Anaerobic Digesters on Wisconsin Farms

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Presentation Goals

1. Outline drivers for farm-based anaerobic digestion projects

2. Describe the anaerobic digestion process and commercially available technologies

3. Discuss the options for electrical generation, solids separation and thermal energy recovery

4. Summarize farm-based anaerobic digestion systems in Wisconsin

5. Describe UW-Green Bay research projects related to anaerobic digestion, as well as other potential research opportunities

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Introduction

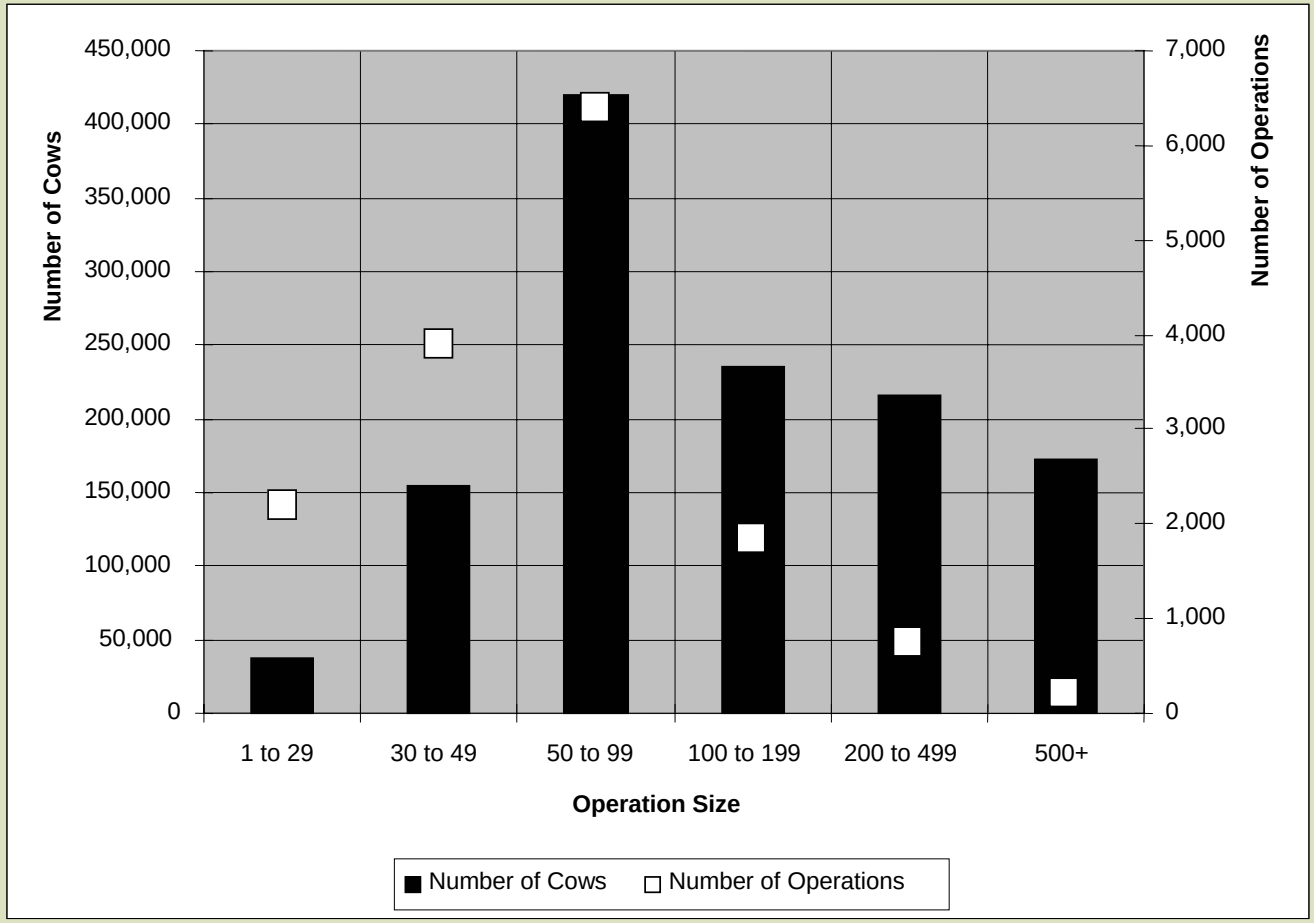
- **Anaerobic digestion is not a new technology**
  - **One of the oldest processes used by POTWs for biosolids stabilization**
  - **New variations developed over the last several decades**
- **Anaerobic digestion is being more closely evaluated by industry and agriculture**
  - **Food processors (dairy, vegetable, brewing, etc.)**
  - **Meat packers**
  - **Large dairy farms**
- **Wisconsin is currently the national leader in farm-based anaerobic digestion systems**
  - **Efforts of Focus on Energy, Biogas Working Group, equipment installers and others**

Potential Drivers for Manure Based Anaerobic Digestion Projects

- **Increasing farm size**
  - **Size of the "problem" or "opportunity" increases**
  - **Minimum size requirement for anaerobic digestion is generally considered to be 500 cows**
    - **Research being done on small-scale systems**

- **Increasing environmental scrutiny**
  - **Facility based issues**
    - **Manure storage**
    - **Odors**
    - **Green house gas emissions**
  - **Land application and associated water quality issues**
    - **Nutrient management (N, P and K)**
    - **Pathogens**

Reality: Dairy Herd Sizes in WI



Source: Wisconsin 2006 Agricultural Statistics, Year 2005 Numbers

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What is Anaerobic Digestion?

- **Process using naturally occurring microorganisms to digest/degrade organic materials in the absence of air**

- **Characterized by temperature**
  - **Mesophilic** **95-105°F**
  - **Thermophilic** **125-135°F**

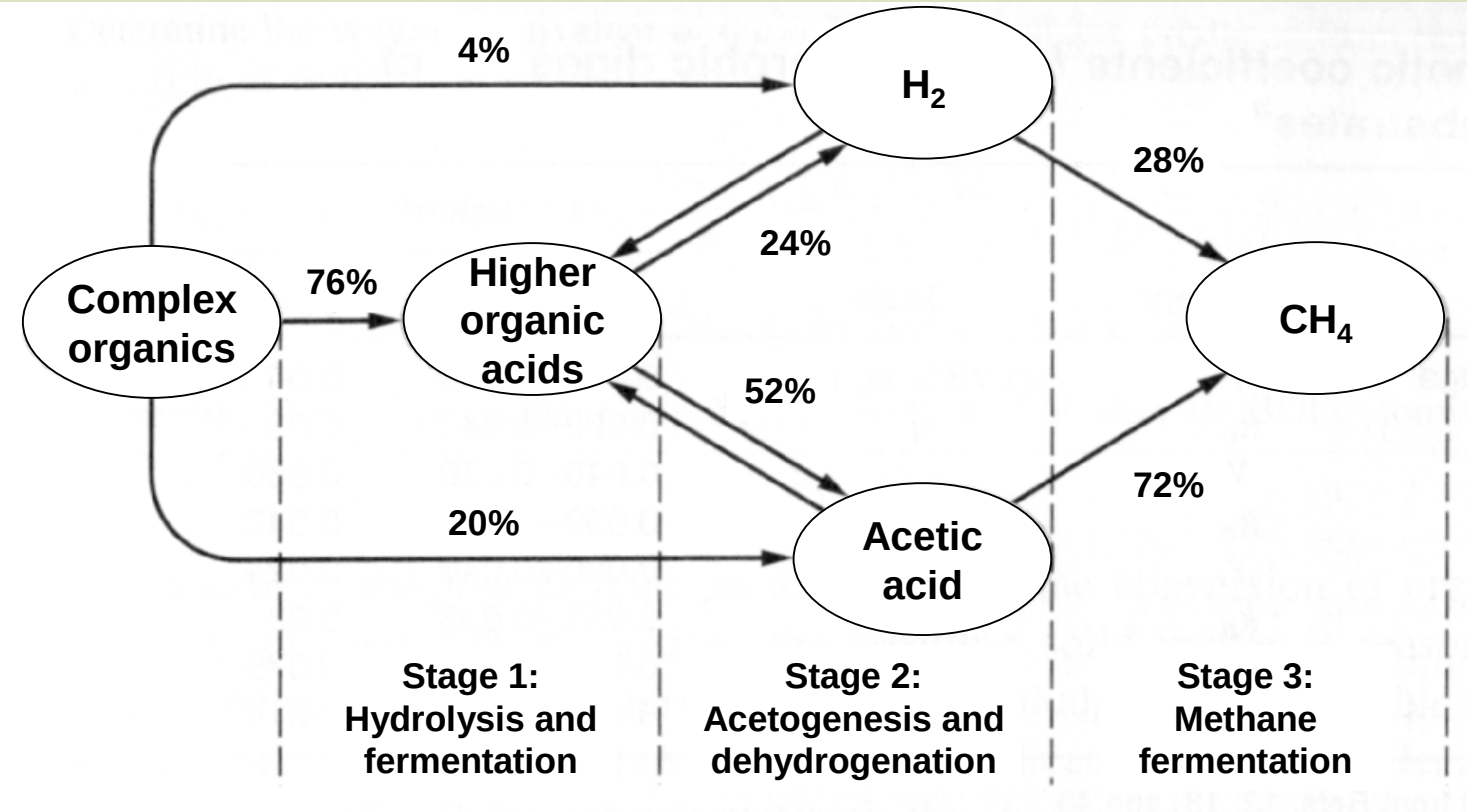
- **Literature indicates that thermophilic bacteria are capable of metabolizing organics at a more rapid rate**

Steps in the Anaerobic Digestion Process

- **Hydrolysis**
  - **Initial conversion of complex organic matter**
- **Acidogenesis**
  - **Fermentation to acids by “acid formers”**
  - **Occurs relatively fast, with limited process concerns**
- **Methanogenesis**
  - **Methane generation by “methane formers”**
  - **Occurs slowly – low doubling rate of methane formers**
    - **Rate limiting step**
  - **Process control of temperature, HRT, pH, etc., is critical**

Steps in the Anaerobic Digestion Process

Source: Metcalf and Eddy, 1991.



Products of Anaerobic Digestion

- **Biogas (CH_4, CO_2, H_2S, trace gases)**
  - **Energy value depends on the methane content**
    - **Typically 60-70% methane**
    - **600-700 Btu per cubic foot**
  - **Moisture and H_2S content of the biogas are critical concerns for the operation of electrical generation equipment**
    - **Equipment issues are often more critical than the biological process**

- **Biosolids**
  - **Value will depend on ability to "capture" the solids from the digester effluent and produce a value-added product**

Solids Separation Systems

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Critical Issues for Solids Separation

- **Solids capture rate**
- **Solids percentage of the final product**
- **Fate of the nutrients**
- **Reliability**
- **Capital and O&M Costs**

<u>Common technologies</u>

- **Screens**
- **Screw presses**

Optional polymer addition can increase solids capture rate and nutrient recovery in the solids

Anaerobic Digestion Systems: Covered Lagoons

- **Primarily used for large volume, low solids manure**
- **Impermeable cover traps gas generated during anaerobic decomposition**
- **General characteristics:**
  - **No mixing or temperature control**
    - **Climate sensitive**
  - **Long detention times (60+ days)**
  - **Lowest cost systems**
  - **Odor reduction and minimal energy recovery can be achieved**

Anaerobic Digestion Systems: Plug Flow

- **Primarily used for high solids manure**
  - **Move through as a plug (i.e., like toothpaste)**
- **Flexible or rigid covers for gas collection**
- **General Characteristics:**
  - **Temperature control with no mixing**
  - **Detention times (15-30 days)**
  - **Normally operated at mesophilic temperatures**
  - **Solids deposition may be a problem for sand/grit or if the solids content changes substantially**
    - **Type of bedding used by the dairy**
    - **Summer use of misters/sprinklers**

Example: Plug Flow System

Anaerobic Digestion Systems: Complete Mix

- **Primarily used for manure in a range of 3-10% solids**
- **Digester can be above or below ground**
- **General Characteristics**
  - **Temperature control with mixing**
  - **Detention times (15-20 days)**
  - **Can be operated at mesophilic or thermophilic temperatures**
  - **Capital cost can be somewhat higher**

Example: Complete Mix System

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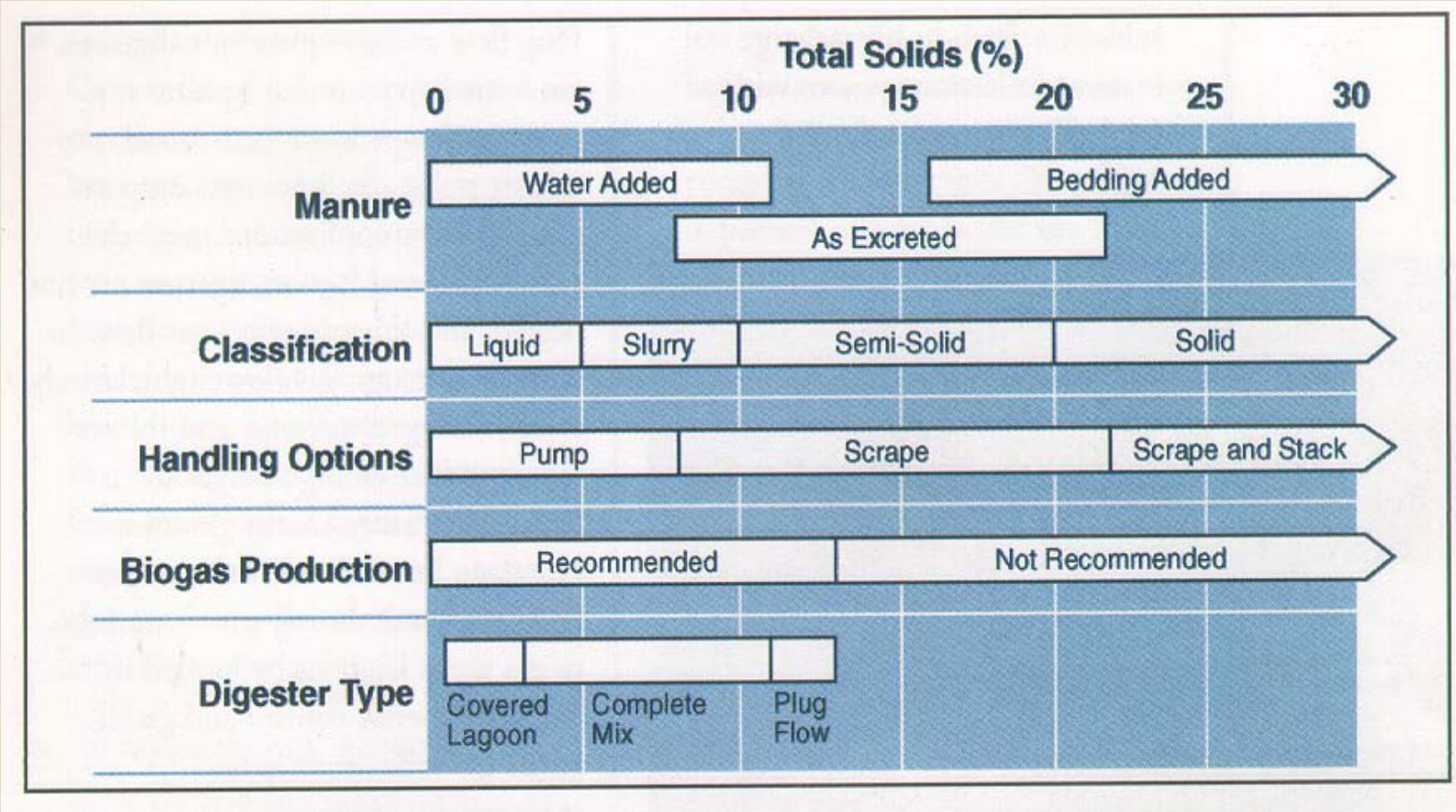
Example: Solids Concentration



Biogas Utilization Options

- **Internal combustion engines/generators**
- **Microturbines**
  - **Currently more common for POTW or landfill applications**
- **Significant Operational Issues**
  - **Connecting to the grid**
  - **Biogas quality requirements**
    - **Gas cleaning systems are often required**
    - **Cost and reliability are issues**
  - **Thermal energy recovery**
    - **Digester heating**
    - **Space heating**
    - **Other uses**

Internal Combustion Engines

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Microturbines

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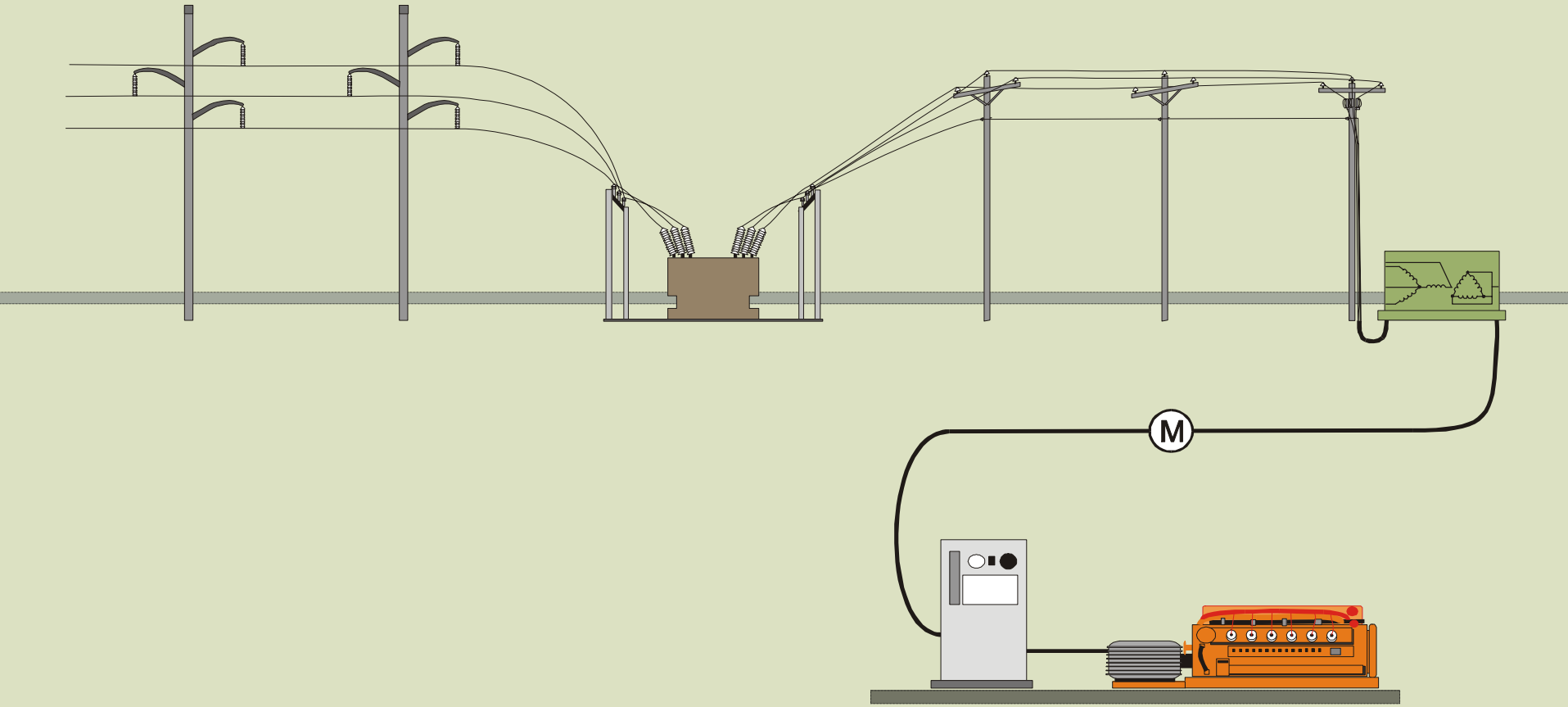
Simplified Electrical Distribution System



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Electrical Generation

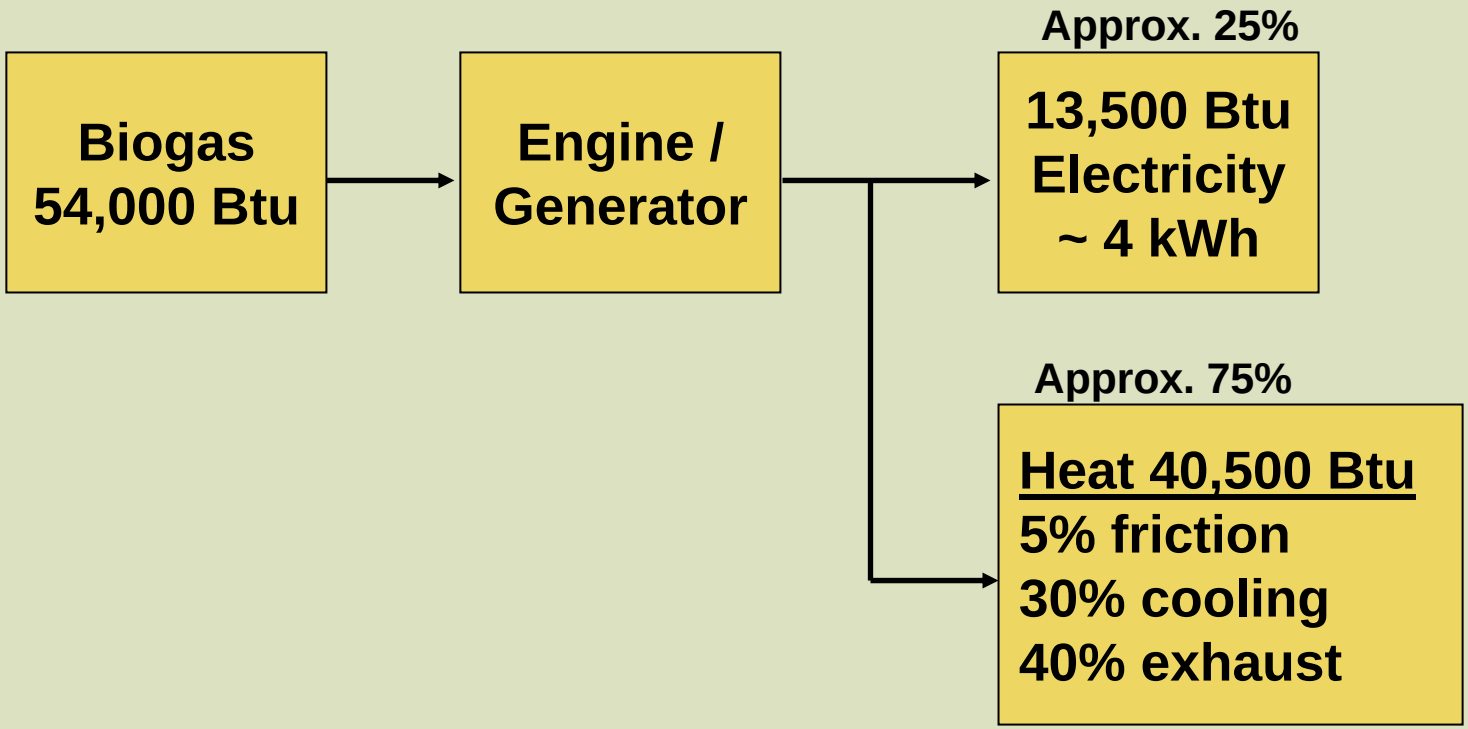
Dairy, plug-flow **90 ft^3/cow/day**

@ 600 Btu/ Ft^3 Methane
Generator efficiency ~ 25%

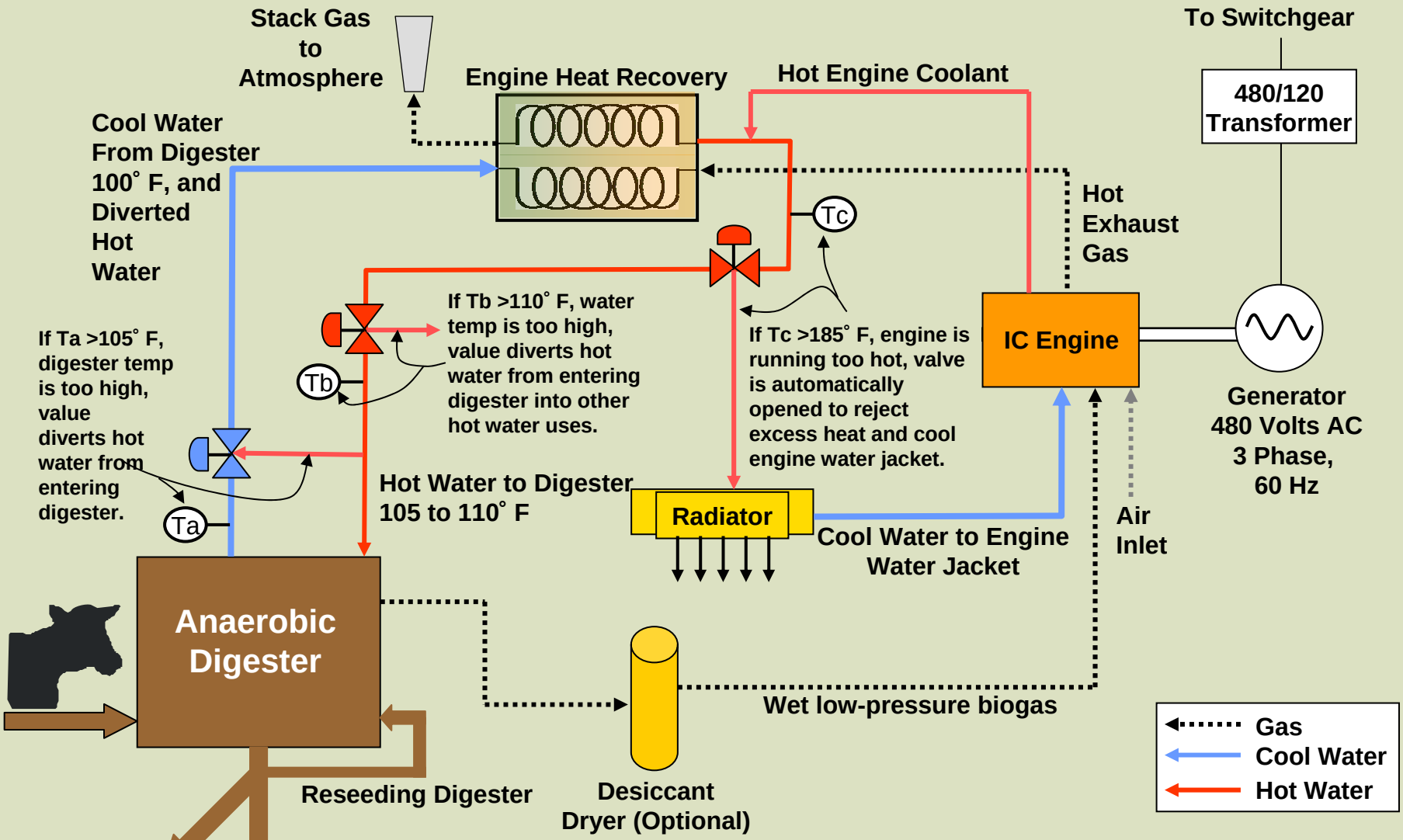
~ 4 kWh per cow/day

Need 6 cows to meet the electrical needs for a typical household, which uses approximately 700 kWh/month

Combined Heat and Power Systems



Anaerobic Digester / IC Engine-Generator



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Costs of Manure Based Anaerobic Digestion Projects

- **Installed cost of approximately $1000/cow**
  - **10% for feasibility study, design and engineering**
  - **45% for electrical equipment**
  - **35% for the anaerobic digestion system**
  - **10% for manure collection/equalization**
- **Several potential financing options may be available**

Potential Benefits of Manure Based Anaerobic Digestion Projects

- **Biogas Utilization**
  - **Power generation and thermal energy recovery**
  - **Green power credits**
    - **New RPS requirements in Wisconsin**
    - **Example: We Energies "Biogas Buyback Rate"**
      - **$0.08/kWh on peak**
      - **$0.049/kWh off peak**
  - **Income from processing off-site wastes**
    - **Cannot exceed 10% of total volume unless permitted**
  - **Greenhouse gas credits**

Potential Benefits of Manure Based Anaerobic Digestion Projects

- **Biosolids Utilization**
  - **More homogenous effluent is generated**
    - **IMPORTANT NOTE: Little change in nutrient content occurs because of anaerobic digestion**
  - **Solids may be utilized/sold for bedding, soil amendments and fertilizer**
    - **Bedding saving of $40-50/cow/year**
    - **Often critical for project economics because of low electrical rates in the Midwest**
      - **Payback of 13 years without solids separation and 6 years with solids separation**

Farm Digesters in the U.S.
Source: AgSTAR, 2006

State	Operating Anaerobic Digestion Systems	Total Energy Production (1,000 kWh/yr)
Wisconsin	21	72,927
California	18	49,380
New York	13	8,935
Pennsylvania	11	9,966
Iowa	5	3,066
Illinois	4	3,154
Texas	3	19,447

Farm Name and Location	Farm Type head	Digester Type	Biogas Use	Heat Application
Five Star Dairy Elk Mound	Dairy (910)	Microgy complete-mix, thermophilic	Electricity generation	Digester
Wild Rose Dairy LaFarge	Dairy (900)	Microgy complete-mix , thermophilic	Electricity generation	Digester
Baldwin Dairy Baldwin	Dairy (1,225)	Clay-lined lagoon with poly cover (ambient temperature)	Flared, no use	None
Emerald Dairy Emerald	Dairy (1,600)	Poly-lined lagoon with poly cover (ambient temperature)	Flared, no use	None
Double S Dairy Markesan	Dairy (1,100)	Mixed plug-flow loop	Electricity generation	Digester, parlor floor, offices, shop floor
Gordondale Farms Nelsonville	Dairy (850-900)	Mixed plug-flow loop	Electricity generation	Digester, dairy parlor, offices, engine room, warm water flush flume
Stencil Farm Denmark	Dairy (1,000)	Plug-flow mesophilic	Electricity generation	Digester
Quantum Dairy Weyauwega	Dairy (1,200)	Modified plug-flow, mesophilic	Electricity generation	Digester
Vir-Clar Farms Fond du Lac	Dairy (1,350)	Complete-mix, mesophilic	Electricity generation	Digester

Farm Name and Location	Farm Type head	Digester Type	Biogas Use	Heat Application
Holsum Dairy Hilbert – Irish Rd	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Norswiss Digester Elk Mound	Dairy (1,300)	Complete-mix, thermophilic	Electricity generation	Digester
Suring Community Dairy Suring	Dairy (1,000)	Complete-mix, mesophilic	Electricity generation	Digester
Green Valley Dairy Green Valley	Dairy (2,500)	Complete-mix, mesophilic	Electricity generation	Digester
Lake Breeze Dairy Malone	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Holsum Dairy Hilbert – Elm Rd	Dairy (3,000)	Modified plug-flow, mesophilic	Electricity generation	Digester
Clover Hill Dairy	Dairy (1,050)	Modified plug-flow, mesophilic	Electricity generation	Digester
Crave Brothers Farm	Dairy (700 + whey)	Complete-mix, mesophilic	Electricity generation	Digester

Wisconsin Anaerobic Digestion Systems: Complete-mix Mesophilic

- **Vir-Clar Farm and Green Valley Dairy**
  - **Biogas Nord Systems**
    - **Cylindrical concrete tanks**
    - **Mechanical mixing and internal heat exchange**
    - **Inflatable membrane cover**
  - **350 kW at Vir-Clar and 550 kW at Green Valley**

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Wisconsin Anaerobic Digestion Systems: Complete-mix Mesophilic

- **Suring Dairy and Crave Brothers Farm**
  - **AMBICO Digester Systems**
    - **Stainless steel tanks**
    - **Mechanical mixing and internal heat exchange**
    - **10% whey addition at Crave Brothers**
  - **250 kW at Suring and 250 kW at Crave Brothers**

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Wisconsin Anaerobic Digestion Systems: Complete-mix Thermophilic

- **Five Star Dairy and Wild Rose Dairy**
  - **Microgy Digester Systems**
    - **20 day detention time**
    - **Thermophilic temperature**
    - **Biogas sold to Dairyland Power, which owns the electrical generation equipment and is responsible for on-site maintenance**
    - **Estimated payback of 10 years**
  - **Many similar digestion systems have been installed in Europe over the past several decades**

Wisconsin Anaerobic Digestion Systems: Mixed Plug Flow

- **Double S Dairy and Gordondale Farms**
  - **GHD Digester Systems**
    - **20 day detention time**
    - **Mesophilic temperature, with internal heat exchange**
    - **Mixing is done in zones within the digester using biogas**
    - **Fixed cover, pre-cast concrete with an insulating foam coating**

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Wisconsin Anaerobic Digestion Systems: Plug Flow

- **Stencil Farms**
  - **20 day detention time**
  - **Mesophilic temperature**
  - **Inflatable membrane cover**
  - **Internal heat exchange**
    - **Operational issue developed because of hard water coating pipes and reducing heat exchange capacity**

UW-Green Bay Research Projects Related to Anaerobic Digestion

- **Tinedale Farms (TPAD and Solids Separation)**
  - **UW System Applied Research Grant**
  - **DOE Grant**
  - **ADD Grant**
- **Anaerobic Photocatalysis (New Technology)**
  - **Focus on Energy Grant**
  - **UW System Applied Research Grant**
- **CBT and Growing Power (Acid Digestion)**
  - **DATCP Grant**

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Tinedale Farms

UWGB Graduate Students in ES&P
Joe Raboin
Anne Schauer (Ph.D student at MU)

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Anaerobic Photocatalysis

- **Utilization of a photocatalytic process for the production of methane**
  - **Eliminate the need for methane forming bacteria, the rate limiting step in the anaerobic digestion process**

- **Questions that still need to be addressed**
  - **Rate constants for the chemical reaction**
  - **Technical and economic feasibility**
    - **Parasitic power, catalyst lifespan, etc.**
  - **Applicability to other substrates**

Acid Digestion: CBT and Growing Power

Governor Richardson, Mark Heffernan, Will Allen and Governor Doyle

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Other Research Activities / Opportunities

- **Performance comparison of existing anaerobic digestion systems**
  - **AgSTAR and USDA, in conjunction with Focus on Energy**
- **Development of modular or small-scale anaerobic digestion systems that would be applicable for smaller farms**
  - **RFP issued in Minnesota**
- **Evaluation of co-digestion of various substrates**
- **Analysis of regional/community anaerobic digestion systems**
  - **Dane County project**

Potential Research Opportunities (continued)

- **Enhanced use of thermal energy from farm-based anaerobic digestion systems**

- **Improved solids separation processes**
  - **Separation equipment**
  - **Value-added products from separated solids**
  - **Nutrients utilization**

- **Evaluation of other "non-economic" benefits**
  - **Odor control**
  - **Pathogen destruction**

Conclusions

- **Wisconsin is the national leader in farm-based anaerobic digestion systems**
- **Anaerobic digestion is being considered as a way to make large farms environmentally acceptable**
- **Anaerobic digestion appears to be economically viable for farm-based applications when properly designed and coupled with solids separation/utilization**
- **Questions relating to nutrient management remain**

Conclusions (continued)

- **Technology innovations are expected in next few years**
- **Many R&D opportunities exist for the application and expansion of anaerobic digestion to other industries/byproducts**

Questions?

Thank You

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